U.S. and South Korean Cooperation in the World Nuclear Energy Market: Major Policy Considerations

Mark Holt
Specialist in Energy Policy

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Summary

A South Korean consortium signed a contract in December 2009 to provide four commercial nuclear reactors to the United Arab Emirates (UAE), signaling a new role for South Korea in the world nuclear energy market. The $20 billion deal indicates that South Korea has completed the transition from passive purchaser of turn-key nuclear plants in the 1970s to major nuclear technology supplier, capable of competing with the largest and most experienced nuclear technology companies in the world.

In the 1970s, South Korea launched its nuclear power program through the government-owned Korea Electric Company (now Korea Electric Power Corporation, KEPCO), which purchased the country's first nuclear power units from Westinghouse. In the early years of the Korean nuclear program, Westinghouse and other foreign suppliers delivered completed plants with minimal Korean industry input. After the first three units, Korean firms took over the construction work on subsequent plants, although the reactor systems, turbine-generators, and architect/engineering services continued to be provided primarily by non-Korean companies. In 1987, KEPCO embarked on an effort to establish a standard Korean design, selecting the System 80 design from the U.S. firm Combustion Engineering as the basis. Combustion Engineering won the competition for the Korean standard design contract by agreeing to full technology transfer, according to KEPCO. The technology transfer program resulted in the development of the APR-1400 power plant, which is the design purchased by the UAE.

In the UAE deal, the South Korean consortium is headed by KEPCO and includes other major Korean industrial companies that are involved in Korea's rapidly growing domestic nuclear power plant construction program. The consortium also includes Pittsburgh-based Westinghouse Electric Company, which currently owns the U.S. design on which the Korean design is based, and the Japanese industrial conglomerate Toshiba, which now owns most of Westinghouse. Because the AP-1400 is based on a U.S. design, U.S. export controls will continue to apply.

U.S.-Korean nuclear energy cooperation is conducted under a "123 agreement" required by Section 123 of the Atomic Energy Act of 1954. The current agreement was signed in 1973 and will expire on March 19, 2014. A new 123 agreement does not require congressional approval, but it must lie before Congress for 90 days of continuous session before going into effect.

As with most U.S. 123 agreements, the existing U.S.-Korean agreement requires U.S. consent for any reprocessing or enrichment activities related to U.S.-supplied materials and technology. Korea is requesting that the new 123 agreement include U.S. advance consent for future Korean civilian reprocessing and enrichment activities. The United States has opposed the idea, on grounds of general nonproliferation policy and the complications that such activities might pose for other security issues on the Korean peninsula. To comply with the 90-day congressional review requirement, a new agreement probably would need to have been submitted to Congress by spring 2013. Any lapse in the agreement could affect exports of U.S. nuclear materials and reactor components to Korea, potentially affecting ongoing construction of the UAE project.

With time running out to address the fundamental U.S. and Korean differences over reprocessing, the two countries announced on April 24, 2013, that they would extend the existing agreement by two years to allow for additional negotiations. Legislation to authorize the two-year extension was introduced by Representative Royce on June 20, 2013 (H.R. 2449).

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Introduction: South Korea's New World Role

The December 2009 contract by a South Korean consortium to provide four commercial nuclear reactors to the United Arab Emirates (UAE) signaled a new role for South Korea in the world nuclear energy market. The $20 billion deal indicates that South Korea (the Republic of Korea, ROK) has completed the transition from passive purchaser of turn-key nuclear plants in the 1970s to major nuclear technology supplier, now capable of competing with the largest and most experienced nuclear technology companies in the world.

Because the plants being exported by South Korea are based on a U.S. design, U.S. export controls will continue to apply. Westinghouse obtained the necessary authorization in March 2010 from the U.S. Department of Energy (DOE) to transfer information related to the technology to the UAE.[1] A December 2009 peaceful nuclear cooperation agreement between the UAE and the United States, required for nuclear trade by Section 123 of the Atomic Energy Act, was intended to ease weapons proliferation concerns by stipulating that the UAE would not develop fuel cycle facilities to support its planned nuclear power program. The UAE program may establish a precedent for U.S. policy on future Korean exports to non-nuclear power nations, which is likely to be of continuing congressional interest.

South Korea's growing status in the world nuclear market is an important consideration in the renewal of the existing U.S.-Korea nuclear cooperation agreement, which expires in March 2014. South Korea wants the new "123 agreement" to include advance U.S. consent for reprocessing of spent nuclear fuel and enrichment of uranium—sensitive fuel cycle technologies that are not currently permitted. The Korean Minister of the Knowledge Economy called for Korea to achieve "peaceful nuclear sovereignty" under future U.S. agreements.[2] Korea contends that it needs to be able to offer full fuel cycle services to potential nuclear reactor customers in order to compete worldwide. The United States is concerned about the nuclear weapons proliferation implications of such an expansion of enrichment and reprocessing, along with its potential impact on other security issues on the Korean peninsula. Congress will have an opportunity to review any new agreement before it takes effect.

With time running out to address the fundamental U.S. and Korean differences over reprocessing, the two countries announced on April 24, 2013, that they would extend the existing 123 agreement by two years to allow for additional negotiations. Legislation to authorize the two-year extension was introduced by Representative Royce on June 20, 2013 (H.R. 2449).

South Korea's nuclear technology progression has been similar to the earlier nuclear paths of France and Japan, which appear likely to be followed in the future by China. France, Japan, and now South Korea developed their nuclear power industries with technology and designs licensed from U.S. companies to supply domestic energy needs. In each case, the licensees assumed progressively greater responsibility for construction of the U.S.-designed units and eventually the engineering and design as well. The foreign firms now compete for nuclear plant contracts throughout the world, including the United States, either in consortia with their former U.S. licensors or independently.

[1] Presentation by Westinghouse Electric Company President Aris Candris, December 1, 2011.

[2] "Seoul Wants 'Sovereignty' in Peaceful Nuclear Development," *Chosun Ilbo*, December 31, 2009.

In the UAE deal, the South Korean consortium is headed by government-owned Korea Electric Power Corporation (KEPCO) and includes other major Korean industrial companies that are involved in Korea's rapidly growing domestic nuclear power plant construction program. The consortium also includes Pittsburgh-based Westinghouse Electric Company, which currently owns the U.S. design on which the Korean design is based, and the Japanese industrial conglomerate Toshiba, now the majority owner of Westinghouse.

Although Korean companies now take the lead on design and construction of Korea's nuclear power plants, Westinghouse still provides support under the design license. Such support typically includes components, instrumentation and control equipment, and technical and engineering services. The Korean plant to be built in the UAE, the APR-1400 model, is a modified version of the System 80+ design developed by the U.S. firm Combustion Engineering (C-E), which was later acquired by Westinghouse. The total value of components and services to be provided for the UAE project by Westinghouse and other U.S. companies is estimated at about $2 billion, according to a financial package approved in September 2012 by the U.S. Export-Import Bank.[3]

Domestic South Korean Nuclear Energy Program

When the construction of South Korea's first commercial nuclear power plant began in 1972, the South Korean economy was about 7.5% the size of Japan's, and the country's per-capita income was slightly lower than that of North Korea.[4] With such a relatively small industrial base, South Korea's plans to finance and operate a fleet of nuclear power plants could have been considered overly ambitious, and its long-term plans to master the new technology might have seemed unrealistic. But the subsequent growth of the South Korean economy—with per-capita income now rivaling other developed nations and GDP nearly 20% of Japan's—turned out to be more than sufficient to sustain the country's planned nuclear power development.

South Korea launched its nuclear power program through the government-owned Korea Electric Company (now Korea Electric Power Corporation, KEPCO), which purchased the country's first nuclear power units from Westinghouse. Those first plants were ordered on a turn-key basis, in which the foreign supplier delivered a completed plant with minimal Korean industry input. As shown in **Figure 1**, the first of these turn-key units, Kori 1, began operating in 1978. Westinghouse supplied the reactor and other components of the nuclear steam supply system (NSSS) and constructed the plant, and other western firms provided the turbine-generator and architect/engineering services. Wolsong 1 and Kori 2, coming on line in 1983, were also turn-key units, with all major components and construction services provided primarily by non-Korean companies.

After those first three units, Korean firms took over the construction work on subsequent plants, beginning with Kori 3, which began commercial operation in 1985. However, the NSSS, turbine-generators, and architect/engineering services continued to be provided primarily by non-Korean companies, including Westinghouse, Atomic Energy of Canada Limited (AECL), and the French

[3] Freebairn, William, "U.S. Portion of UAE Project Grew Due to Long-Term Funds, Rates: Ex-Im," *Nucleonics Week*, December 6, 2012.

[4] Angus Maddison, *The World Economy: Historical Statistics*, Organization for Economic Cooperation and Development, 2006, pp. 298-306.

firm Framatome, which had previously licensed its design from Westinghouse. That arrangement continued for the next six units, which came on line from 1995-1999.

In 1987, KEPCO embarked on an effort to establish a standard Korean design, selecting the System 80 design from the U.S. firm Combustion Engineering (C-E) as the basis.[5] The System 80 design had been used for three identical units nearing completion at Palo Verde, AZ.

[5] World Nuclear Association, "South Korea Country Report," December 2012, http://www.world-nuclear.org/info/inf81.html.

Figure 1. South Korean Nuclear Power Units

Major Categories of Work Conducted By Domestic and Foreign Companies

Year of Operation/ Reactor Name	Reactor Supplier	Generator Supplier	Architect Engineer	Construction Contractor
1978 Kori 1	Westinghouse	GE (UK)	Gilbert	Westinghouse
1983 Wolsong 1	AECL	NE (UK)	AECL	AECL
1983 Kori 2	Westinghouse	GE (UK)	Gilbert	Westinghouse
1985 Kori 3	Westinghouse	GE (UK)	Bechtel	Hyundai
1986 Kori 4	Westinghouse	GE (UK)	Bechtel	Hyundai
1986 Yonggwang 1	Westinghouse	Westinghouse	Bechtel	Hyundai
1987 Yonggwang 2	Westinghouse	Westinghouse	Bechtel	Hyundai
1988 Ulchin 1	Framatome	Alstom	Framatome	Dong Ah/Hanjung
1989 Ulchin 2	Framatome	Alstom	Framatome	Dong Ah/Hanjung
1995 Yonggwang 3	Hanjung/C-E	Hanjung/GE	KOPEC/S&L	Hyundai
1996 Yonggwang 4	Hanjung/C-E	Hanjung/GE	KOPEC/S&L	Hyundai
1997 Wolsong 2	AECL/Hanjung	Hanjung/GE	AECL/KOPEC	Hyundai
1998 Wolsong 3	AECL/Hanjung	Hanjung/GE	AECL/KOPEC	Daewoo
1998 Ulchin 3	Hanjung/C-E	Hanjung/GE	KOPEC/S&L	Dong Ah/Hanjung
1999 Wolsong 4	AECL/Hanjung	Hanjung/GE	AECL/KOPEC	Daewoo
1999 Ulchin 4	Hanjung/C-E	Hanjung/GE	KOPEC/S&L	Dong Ah/Hanjung
2002 Yonggwang 5	Doosan	Doosan	KOPEC	Hyundai/Daelim
2002 Yonggwang 6	Doosan	Doosan	KOPEC	Hyundai/Daelim
2004 Ulchin 5	Doosan	Doosan	KOPEC	Dong Ah/Doosan/Samsung
2005 Ulchin 6	Doosan	Doosan	KOPEC	Dong Ah/Doosan/Samsung

Non-Korean Companies

Non-Korean and Korean Companies

Korean Companies

AECL: Atomic Energy of Canada Ltd.
C-E: Combustian Engineering
GE: General Electric
KOPEC: Korea Power Engineering Company
NE: Northern Engineering
S&L: Sargent & Lundy

Source: Nuclear News, *World List of Nuclear Power Plants*, March 2009.

Combustion Engineering won the competition for the Korean standard design contract by agreeing to full technology transfer, according to KEPCO. A 10-year technology license agreement was signed in 1987 and extended for 10 more years in 1997. The U.S. contractors for

the turbine-generators (General Electric) and architect/engineering services (Sargent & Lundy) agreed to transfer key technology as well.

All of the major U.S. companies working on the new C-E plants agreed to serve as subcontractors to Korean firms: Combustion Engineering to Hanjung (now Doosan), General Electric (GE) also to Hanjung, and Sargent & Lundy (S&L) to Korea Power Engineering Company (KOPEC), which is majority owned by KEPCO.[6] Yonggwang 3 and 4 and Ulchin 3 and 4, which began operating from 1995 to 1999, were constructed under that arrangement. A similar partnership was formed with Atomic Energy of Canada Limited (AECL) to build Wolsong 2-4, completed during 1997 through 1999. Plant construction continued to be carried out by Korean companies. Components and work shared by Korean and foreign firms are shown in **Figure 1**.

Korean reactor designers worked with C-E, which became part of Westinghouse in 2000, to develop a standard Korean design from the System 80 model. This effort resulted in the 1,000 megawatt Optimized Power Reactor (OPR-1000). The seven OPR-1000 units that have been completed since 1999 were built and constructed almost entirely by Korean firms. However, some key components continued to be supplied or heavily supported by non-Korean firms, constituting a small percentage of each nuclear unit's total cost.

Development of a larger and more advanced model of the Korean standard design was based on the C-E System 80+ design that received U.S. standard design certification from the Nuclear Regulatory Commission (NRC) in May 1997. The Korea Atomic Energy Research Institute (KAERI) helped develop the U.S. design,[7] complementing work on the Korean version of the design that began in 1992. The Korean design was largely completed by 1999 and was designated the APR-1400.[8]

South Korea currently has four nuclear units under construction, one OPR-1000 and three APR-1400s, to be completed between 2013 and 2017. Five more APR-1400s are planned to be completed between 2018 and 2021. That construction program would increase the country's nuclear power reactors from 23 to 32, and nuclear power generating capacity from 20,800 megawatts to 32,500 megawatts.[9] South Korea's long-term electricity plan calls for increasing nuclear capacity to 42,700 megawatts by 2030, the equivalent of about seven additional APR-1400s after 2021.[10] South Korea generated 35% of its electricity from nuclear plants in 2011[11] and plans to increase that share to 59% by 2030.[12]

Ever since South Korea completed the first nuclear unit in which Korean firms participated in all phases of development—Yonggwang 3 in 1995—the country has opened an average of about one

[6] Gary Baker and Shin Ho-Chul, "Korean Utility and Three U.S. Firms Ink Nuclear Building Deal," *Nucleonics Week*, April 16, 1987, p. 5.

[7] National Academy of Sciences, *Nuclear Power: Technical and Institutional Options for the Future*, Washington, DC, 1992, p. 100.

[8] World Nuclear Association, "South Korean Country Report," op. cit.

[9] World Nuclear Association, "South Korean Country Report," op. cit.

[10] Korea Atomic Energy Research Institute, *Nuclear Power and R&D Programs in Korea*, Presentation to CRS visitors, Daejeon, South Korea, July 27, 2009, pp. 11-12.

[11] World Nuclear Association, "Nuclear Share Figures, 2001-2011," http://www.world-nuclear.org/info/nshare.html.

[12] Jae-min Ahn, "Industry Perspectives on Korean Nuclear Program," Presentation to U.S.-ROK Workshop on Nuclear Energy and Nonproliferation, Washington, DC, January 20, 2010.

unit every 18 months. Starting after the most recent reactor, Shin Wolsong 1, began commercial operation in July 2012, South Korea plans to complete an average of about one reactor per year through 2030. With the planned rate of domestic nuclear plant construction remaining fairly stable, it would appear that any significant expansion of South Korea's nuclear engineering and construction industry would depend on exports.

South Korean Nuclear Plant Export Program

The South Korean government expects KEPCO's reactor sale to the UAE to constitute the leading edge of a much larger nuclear power marketing effort throughout the world. According to news media reports, the Ministry of Knowledge Economy (MKE), which is responsible for industrial and trade policy, had established a goal for South Korea to capture 20% of the world nuclear power plant market during the next 20 years. Based on an estimated world market of about 400 large commercial reactors through 2030, a 20% penetration would result in South Korean exports of 80 reactors during the next 20 years, with an estimated value of $400 billion.[13] There have been recent indications that South Korea is scaling back those targets, as well as its expectations for world nuclear growth, but the country is competing vigorously for export sales, particularly in the Middle East and North Africa.[14]

UAE Reactor Contract

As South Korea's first foreign reactor sale, the UAE contract for the four-unit Barakah plant is likely to establish a template for future exports. The companies involved in the UAE project appear to be the same ones that are currently building Korean domestic nuclear plants and are likely to play similar roles in the export program. The importance placed by the ROK government on the contract was underscored by the presence of South Korean President Lee Myung-bak at the signing ceremony in the UAE December 27, 2009, along with UAE President Sheikh Khalifa bin Zayed al-Nahayan.[15] Construction of the first Barakah reactor officially began in July 2012.[16]

The selection of the KEPCO consortium was made by the Emirates Nuclear Energy Corporation (ENEC), which will oversee the contract's implementation. According to a statement issued by ENEC, the contract includes the following major provisions:[17]

- The KEPCO consortium will design, build, help operate and maintain, and provide initial fuel for four APR-1400 nuclear units at a total cost of about $20 billion. A "high percentage of the contract" will be under a fixed price.

[13] World Nuclear News. "South Korea Weeks to Boost Reactor Exports," January 13, 2010, http://www.world-nuclear-news.org/NP-South_Korea_seeks_to_boost_reactor_exports-1301104.html.

[14] World Nuclear Association, "Nuclear Power in South Korea," May 29, 2013, http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/South-Korea.

[15] Amena Bakr, "South Korean Group Wins $40bn UAE Nuclear Deal," *Arabian Business.com*, December 27, 2009.

[16] World Nuclear Association, "Nuclear Power in the United Arab Emirates," September 2012, http://www.world-nuclear.org/info/UAE_nuclear_power_inf123.html.

[17] Emirates Nuclear Energy Corporation, "UAE Selects Korea Electric Power Corp. Team as Prime Contractor for Peaceful Nuclear Power Program," press release, December 27, 2009, http://www.enec.gov.ae/news/uae-selects-korea-electric-power-corp-team-as-prime-contractor-f/.

- Korean investors will have an equity interest in the UAE plants.
- The first unit is to begin commercial operation in 2017, with the other three to be completed by 2020.
- Extensive training, human resources development, and education is to be provided to allow UAE to eventually provide most of the nuclear plant staffing and develop commercial infrastructure and support businesses.
- A potential follow-on contract for long-term operation and maintenance of the Barakah plant, worth as much as another $20 billion over 60 years,[18] is under discussion with KEPCO and other vendors.

The Korean consortium was selected over two other proposals, from Areva and General Electric-Hitachi. According to media reports, the decision was strongly affected by price. One report indicated that the KEPCO total of $20 billion was 30% lower than the Areva bid, which in turn was lower than the GE-Hitachi offer.[19] Another report described KEPCO's price as $16 billion lower than Areva's.[20] KEPCO's bid averages out to $5 billion per reactor, which is higher than a reported estimate of $3.15 billion for each of two APR-1400s being built at the Shin-Kori site in Korea, with the difference ascribed to the additional costs of operating in a country with no previous nuclear experience.[21] The $20 billion cost of 5,600 megawatts of electric generating capacity works out to $3,571 per kilowatt, excluding financing costs, substantially lower than the most recent estimate of $5,339 per kilowatt for U.S. reactors by the Energy Information Administration.[22]

Korean and U.S. Partnership

As noted above, the Korean and U.S. companies involved in the UAE project have worked together extensively in the past on the domestic Korean nuclear power program, with Korean firms gradually taking over most of the work. U.S. participation in future domestic Korean nuclear plants is expected to be very small, but it may be larger in Korean reactor exports such as Barakah. Below are the members of the KEPCO consortium and their roles in the UAE project:

- *KEPCO*. Prime contractor and project integration.
- *Korea Hydro and Nuclear Power Company (KHNP).* Operating company for Korean nuclear power plants. To serve as engineering, procurement, and construction contractor and operator. KEPCO subsidiary.
- *KOPEC*. Nuclear power plant architect/engineering services. Majority owned by KEPCO.
- *Korea Nuclear Fuel Company (KNF)*. Initial nuclear fuel loads.

[18] Bakr, op. cit.

[19] Chris Stanton, "Nuclear Bid to Be Industry Norm," *The National*, December 28, 2009, http://www.thenational.ae/apps/pbcs.dll/article?AID=/20091228/BUSINESS/712289928.

[20] Bakr, op. cit.

[21] Stanton, op. cit.

[22] U.S. Energy Information Administration, "Updated Capital Cost Estimates for Electricity Generation Plants," Table 2, November 2010, http://www.eia.gov/oiaf/beck_plantcosts/index.html.

- *Korea Plant Service and Engineering Company (KPS)*. Plant maintenance.[23] Majority owned by KEPCO.
- *Doosan Heavy Industries & Construction*. Fabrication of nuclear steam supply system and other major components.
- *Samsung C&T Corporation*. Plant construction.
- *Hyundai Engineering and Construction*. Plant construction.
- *Westinghouse Electric Company*. Technical and engineering support services and various components.
- *Toshiba Corporation*. Majority owner of Westinghouse. Role unspecified. Possible component supply and technical consulting.

Westinghouse and other U.S. companies are now expected to carry out about 10% of the work on the Barakah project, double the initial estimates. The Export-Import Bank of the United States in September 2012 approved $2 billion in financing for U.S. equipment and services for Barakah, mostly to be provided by Westinghouse and its U.S. sub-suppliers. "The Barakah project will allow us to maintain about 600 U.S. jobs," Westinghouse said after the Ex-Im Bank financing approval. The Ex-Im Bank estimated that, overall, the $2 billion in financing would "support approximately 5,000 American jobs across 17 states." Items to be supplied by Westinghouse and other U.S. companies include reactor coolant pumps, reactor components, controls, engineering services, and training.[24]

Although most of the U.S. technology involved in the Korean standard reactor designs (OPR-1000 and APR-1400) has been successfully transferred to Korean firms as called for by the initial C-E licensing agreement in 1987, Westinghouse still considers the Korean reactors to be Westinghouse-licensed products. As a result, Korean exports of the APR-1400, such as the UAE project, will be subject to U.S. export control requirements.[25] In addition, certain marketing restrictions under the Westinghouse licensing arrangement have no expiration, and so they have continued under the "business cooperation agreement" that succeeded the original technology license in 2007. The provisions of the business cooperation agreement were applied to the UAE project.[26]

Westinghouse is also partnering with Korean industry to produce control element assemblies for C-E reactor designs, including U.S. and Korean nuclear power plants, as well as the UAE plants and other potential Korean exports. The joint venture between Westinghouse and KNF is being located at the KNF fuel fabrication plant in Daejeon, Korea, and will be 55% owned by Westinghouse.[27]

[23] "KEPCO to Provide Design, Construction and Maintenance of Nuclear Reactors," *Khaleej Times Online*, December 28, 2009.

[24] Export-Import Bank of the United States, "Ex-Im Approves $2 Billion in Financing for Nuclear Power Plant in U.A.E.," news release, September 7, 2012, http://www.exim.gov/newsandevents/releases/2012/ex-im-approves-2-billion-in-financing-for-nuclear-power-plant-in-u-a-e.cfm.

[25] Lopatto, op. cit.

[26] Doosan Senior Vice President Jeong-Yong Park, December 1, 2011.

[27] April Murelio, "Westinghouse, KNF Team to Manufacture Control Element Assemblies," *Nuclear Power Industry News*, February 9, 2009.

Outlook for Korean Exports

The goal set by the Korean Ministry of Knowledge Economy for a 20% South Korean share of the global nuclear power plant market would place South Korea about equal to Russia and behind only France and the United States in the nuclear market, according to a ministry report to President Lee. "Nuclear power-related business will be the most profitable market after automobiles, semiconductors, and shipbuilding," the report said. MKE also called for South Korean firms to expand their share of the estimated $78 billion world market for operation, maintenance, and repair of nuclear power plants.[28] As noted above, those goals may now be considered too optimistic, but South Korea still clearly intends to be a major participant in the world nuclear market.

The UAE contract added substantial credibility to MKE's export goals and changed the dynamics of the world nuclear power market. Kuwaiti officials were paraphrased as saying the UAE price "is likely to become a benchmark for atomic energy technology across the region."[29] After losing the UAE contract, Areva was reported to be examining ways to modify its plant design to cut costs, such as by cutting the number of steam generators from four to two by making them larger, as in the Korean design.[30]

Other potential Korean export deals are under consideration in Indonesia and the United States, Westinghouse's home market. Other countries that have been mentioned in the news media include Vietnam, Malaysia, Thailand, and Middle East neighbors of the UAE.[31] A Korean consortium has reportedly been selected by Jordan to build the kingdom's first research reactor.[32] KNHP signed a preliminary agreement with Indonesian energy firm Medco Energi in July 2007 to build Korean-design reactors in Indonesia. However, Japanese firms are reportedly also under consideration.[33] A U.S. energy development company, Alternate Energy Holdings Incorporated (AEHI), announced in January 2010 that it was negotiating with South Korean officials on an agreement to build APR-1400 nuclear units at proposed sites in Idaho and Colorado. An AEHI news release said, "We expect the agreement to be similar to the UAE agreement announced last week. Such technology should give AEHI a serious competitive advantage."[34] Plans for financing for the proposed projects are unknown, however.

KEPCO took an early step toward exporting the APR-1400 to the United States by meeting with the U.S. NRC November 18, 2009, on possible standard design certification for the reactor. At the "initial pre-application meeting," KEPCO gave a presentation on the Korean nuclear industry, the U.S. and Korean work on developing the System 80+ and the APR-1400, and differences between the two designs. Prospects for NRC certification of the APR-1400 could presumably be helped by

[28] World Nuclear News, op. cit.

[29] Stanton, op. cit.

[30] Ann MacLachlan, "Areva Considering Ways of Cutting Costs of EPR Nuclear Reactor," *Platts Commodity News*, January 11, 2010.

[31] Global Collaborative, "KEPCO/KHNP," http://www.globalcollab.org/Nautilus/australia/reframing/aust-ind-nuclear/ind-np/muria/countries/kepco.

[32] Taylor Luck, "S. Korean Bidder to Build Nuclear Research Reactor in Jordan," *Jordan Times*, April 12, 2009.

[33] "S. Korea, Indonesia Sign Nuclear Cooperation Deal," *Reuters*, July 25, 2007.

[34] Alternate Energy Holdings Incorporated, "AEHI Expects to Close Deal to Import Korean Reactors in Early 2010," press release, January 4, 2010, http://www.alternateenergyholdings.com/LinkClick.aspx?fileticket=gVVisrNAzgI%3d&tabid=1979.

its similarity to the previously certified System 80+. However, NRC officials stressed that "this meeting did not initiate the review of the APR-1400 design certification."[35] NRC's most recent licensing schedule shows the KEPCO design certification review beginning in mid-2013, with no completion date scheduled.[36]

The capacity of the Korean nuclear industry would apparently need to expand to meet MKE's export goals. As noted above, Korea plans to complete an average of about one reactor per year for the domestic market. In addition, Doosan and other firms have been producing major reactor components for non-Korean reactors, such as the four Westinghouse AP-1000 units being built in China. To export 80 units by 2030, as implied by the MKE goal, the Korean industry would have to complete an additional four units per year, a substantial increase over the current rate. However, the total implied construction rate of about five units per year has been achieved by other countries in the past, such as France during the 1980s.[37]

To expand Korea's nuclear plant construction and service capacity, MKE has announced plans to train 2,800 nuclear technical staff by 2011 and invest $350 million in further design improvements, including an increase in research and development personnel. Under the MKE plan, South Korea was to be completely self-sufficient in nuclear reactor technology by 2012.[38]

Research and Development Cooperation

Nuclear R&D cooperation between the United States and the Republic of Korea dates to the beginning of President Eisenhower's Atoms for Peace program. The first major U.S.-ROK nuclear project, a 100 kilowatt research reactor, began operating in 1962 and was later upgraded to 250 kilowatts and finally to two megawatts. These joint activities were carried out under a series of peaceful nuclear cooperation agreements signed between 1956 and 1965.[39]

Joint research on the nuclear fuel cycle has proved more problematic. Fuel cycle technologies, such as reprocessing spent nuclear fuel to separate plutonium and uranium to make new fuel, can potentially be used to make weapons materials. The current peaceful nuclear cooperation agreement, signed in 1972, requires U.S. consent before South Korea can reprocess spent fuel (Article VIII F).

The United States opposed Korean proposals in the 1970s to develop a conventional chemical reprocessing plant and conduct related R&D. In the 1980s, Korea proposed to develop the TANDEM fuel cycle, in which spent fuel from Westinghouse and other light water reactors would be dissolved to make fuel for CANDU heavy water reactors, without fully separating weapons-

[35] Nuclear Regulatory Commission, *Korea Electric Power Corporation APR-1400 Presentation*, ML093430109, December 9, 2009, http://adamswebsearch.nrc.gov/scripts/securelogin.pl.

[36] Nuclear Regulatory Commission, "New Reactor Licensing Applications," December 6, 2012, http://www.nrc.gov/reactors/new-reactors/new-licensing-files/new-rx-licensing-app-legend.pdf.

[37] Arnulf Grubler, *An Assessment of the Costs of the French Nuclear PWR Program 1970-2000*, International Institute for Applied Systems Analysis, IR-09-036, Laxenburg, Austria, October 6, 2009, p. 8, http://www.docstoc.com/docs/19721910/Interim-Report-IR-09-036-An-assessment-of-th.

[38] World Nuclear News, op. cit.

[39] Seongho Sheen, "Nuclear Sovereignty versus Nuclear Security: Renewing the ROK-U.S. Atomic Energy Agreement," *Korean Journal of Defense Analysis*, Vol. 23, No. 2, June 2011, pp. 273–288, http://www.brookings.edu/~/media/research/files/papers/2011/8/nuclear%20korea%20sheen/08_nuclear_korea_sheen.pdf.

useable plutonium. However, the United States opposed this plan as well, on the grounds that only one further step would be needed to achieve complete plutonium separation. In the 1990s, the Korea Atomic Energy Research Institute (KAERI) conducted a joint research program with DOE national laboratories and Atomic Energy of Canada Limited on the DUPIC fuel cycle (direct use of PWR spent fuel in Candu), in which light water reactor spent fuel would be made into Candu fuel without reprocessing. However, KEPCO showed little interest in using the technology.[40]

In the 2000s, KAERI began focusing on another spent fuel recycling technology, pyroprocessing, as a way to handle its growing spent fuel inventory while minimizing proliferation issues. Pyproprocessing is an electrometallurgical process in which spent fuel is dissolved in molten salt, and uranium, plutonium, and other higher elements are partially separated though electrodeposition on a cathode. Supporters of the process contend that it is proliferation-resistant because, unlike in conventional chemical reprocessing plants, pyroprocessing facilities cannot separate pure plutonium.[41]

The George W. Bush Administration initially agreed that pyroprocessing would be an appropriate technology for South Korea to pursue, signing an R&D agreement in 2002 under the U.S. Department of Energy (DOE) International Nuclear Energy Research Initiative (I-NERI). In cooperation with various DOE national laboratories, KAERI began developing a continuous pyroprocessing system that it hoped could be economical for commercial-scale operation. As a first step, the Advanced Conditioning Pyroprocess Facility (ACPF) was constructed in a shielded "hot cell" at KAERI to reduce oxide spent fuel to the metal form needed for pyroprocessing.

However, before KAERI could begin operating the ACPF, the Bush Administration decided in 2008 to withhold permission under the U.S.-ROK nuclear cooperation agreement for any spent fuel separation work in Korea, including oxide fuel reduction to metal. Critics of the program had contended that pyroprocessing would violate the 1992 Joint Declaration on Denuclearization of the Korean Peninsula, which forbids nuclear reprocessing.[42] KAERI had contended that pryoprocessing did not constitute "reprocessing," because of the lack of complete plutonium separation, but the Bush Administration decided otherwise.[43]

As an alternative, the Bush Administration suggested a joint R&D program in which all spent fuel separation work would be carried out in the United States, particularly at DOE's Idaho National Laboratory (INL), which already has pyroprocessing equipment. South Korea strongly objected to the proposal and began sponsoring seminars and other informational activities in Washington, DC, in support of its pyroprocessing program. However, U.S. policy did not change, and South Korea agreed to a 10-year Joint Fuel Cycle Study in 2011 in which KAERI scientists would

[40] Jungmin Kang and H.A. Feiveson, "South Korea's Shifting and Controversial Interest in Spent Fuel Reprocessing," *Nonproliferation Review*, spring 2001, p. 70.

[41] Pyroprocessing is also referred to as "electrorefining" or "dry" processing, as opposed to "wet" or "aqueous" conventional processing with water-based chemicals. The most widely used conventional reprocessing technology is called PUREX, for plutonium-uranium extraction.

[42] North Korea subsequently carried out reprocessing and other forbidden nuclear activities, but the United States has urged the North to return to compliance. See Nuclear Threat Initiative, at http://www.nti.org/treaties-and-regimes/joint-declaration-south-and-north-korea-denuclearization-korean-peninsula/.

[43] Kyle Fishman, "IAEA South Korean Concerns Resolved," Arms Control Association, http://www.armscontrol.org/print/3115.

conduct spent fuel separation work at INL and other U.S. facilities, while work in Korea would be restricted to simulated material. Operation of KAERI's ACPF is reportedly still under discussion.

In addition to bilateral research projects, South Korea and the United States work together in several international R&D organizations. The two countries are jointly involved in projects on advanced reactors under the Generation IV International Forum (GIF) and the International Atomic Energy Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). Both are also members of the International Framework on Nuclear Energy Cooperation (IFNEC), focusing on the development of international "reliable comprehensive fuel service arrangements" and R&D priorities. To provide a forum for U.S.-ROK views on nuclear research and other nuclear energy issues, the Joint Standing Committee on Nuclear Energy Cooperation (JSCNEC) has met once a year since 1980.

Renewal of U.S.-ROK 123 Agreement

Under Section 123 of the Atomic Energy Act of 1954 (42 U.S.C. 2153), the United States cannot conduct nuclear energy activities with another country without an agreement on nuclear cooperation, or "123 agreement." The current U.S.-Korea 123 agreement was signed in 1973 and will expire on March 19, 2014. Negotiators from the two countries are working to overcome substantial disagreements about the provisions of a new agreement so that it can take effect before the expiration date.

A new 123 agreement does not require congressional approval, but it must lie before Congress for 90 days of continuous session before going into effect. This gives Congress time to hold hearings on the agreement and potentially pass a disapproval resolution, which, if signed by the President or enacted over his veto, would block the new agreement. Because of the 90-day requirement, a new U.S.-Korea 123 agreement would probably have to be presented to Congress sometime in spring 2013 to avoid a lapse in March 2014.

If the U.S.-ROK agreement expired, NRC would be prohibited from issuing export licenses for nuclear reactors or major components to Korea, and existing licenses would be suspended. NRC also could not issue licenses to export nuclear materials, such as enriched uranium for reactor fuel. Also prohibited would be direct supply of nuclear material by the U.S. government, as well as U.S. government R&D cooperation, such as the 10-year pyroprocessing study.

Under NRC regulations (10 CFR 110, Appendix A), major reactor components that need specific licenses for export, as well as an active 123 agreement, are:

- Reactor pressure vessels,
- On-line fuel changing equipment (for heavy water reactors),
- Complete reactor control rod systems,
- Reactor primary coolant pumps, and
- Essentially complete nuclear facilities.

Minor reactor components can be exported under a general NRC license that does not require a 123 agreement, although "generic assurances" must be provided that such components are for peaceful purposes. Minor components include specific components listed in the NRC regulations,

plus any other components or subcomponents especially designed for a reactor. NRC regulations at 10 CFR 110.26(b) provide a list of countries to which minor reactor components can be exported under a general license. The Republic of Korea is currently included in the list, although it is possible that its status could change if the U.S.-ROK 123 agreement lapses. If South Korea were dropped from the general license list, exporters of minor components could apply for specific licenses, still without the need for a 123 agreement.[44]

Minor reactor components or subcomponents that are not specifically designed for reactor purposes do not need NRC licenses and so would not be directly affected by a lapse in the U.S.-Korea 123 agreement. However, Commerce Department export regulations would continue to apply.

"Special nuclear material," such as fissile isotopes of uranium and other reactor fuel, must have a specific license from NRC for shipments of more than 1 gram. Uranium and other nuclear materials also must have specific licenses for exports above certain levels. Specific licenses for nuclear materials exports cannot be issued without a 123 agreement. Exports below the specified levels can use a general NRC license and do not require a 123 agreement. Such exports cannot go to a country on NRC's embargo list, which does not include South Korea.[45]

Table 1 shows an illustrative list of current NRC specific licenses for U.S. exports to South Korea. Major exports include essentially complete pressurized water reactors (PWRs) from Westinghouse, which took over from the original exporter Combustion Engineering, reactor components, and nuclear materials. Most of the licenses expire on March 18, 2014, immediately before the expiration of the U.S.-ROK 123 agreement.

Table 1.NRC Specific Licenses for Nuclear Exports to ROK (illustrative)

Applicant	Commodity	End Use	Date Received	Expiration Date
H.C. Starck Inc.	Molybdenum-Lanthanum (Mo-La) sheets - 1,500 kg	Amend to: increase the quantity of Mo-La sheets by 1,500 kg to a new cumulative total of 2,500 kg	18-Jun-12	31-Aug-14
Westinghouse	PWR, 950 MWe, 2	Yonggwang 3 & 4, Change licensee from C-E to Westinghouse, pursuant to corporate acquisition	07-Mar-01	18-Mar-14
Westinghouse	PWR, 950 MWe, 2	Ulchin 3 & 4, Change licensee to Westinghouse	07-Mar-01	18-Mar-14
Westinghouse	PWR, 1000 MWe, 2	Yonggwang 5 & 6, Change licensee to Westinghouse	07-Mar-01	18-Mar-14
Westinghouse	PWR, 1000 MWe, 2	Ulchin 5 & 6, Change licensee to Westinghouse	07-Mar-01	18-Mar-14
Westinghouse	Reactor internals; coolant pumps; & App A (5)-(9) Components	Shin Kori 1 & 2, Shin Wolsong 1 & 2	16-Dec-02	18-Mar-14
Westinghouse	App A (1) -(4)	Shin Kori 3 & 4	26-Feb-07	18-Mar-14

[44] David Decker, NRC Office of Congressional Affairs, email relaying staff comments, January 8, 2013.

[45] 10 CFR 110.21, 110.22, 110.23, and 110.28.

Applicant	Commodity	End Use	Date Received	Expiration Date
	Components			
Westinghouse	LEU, 5.00%, & Nat U in various forms	Change licensee to Westinghouse	07-Mar-01	18-Mar-14
Westinghouse	LEU, 5.00%, & Nat U, in various forms	Yonggwang 5 & 6 - Change licensee to Westinghouse	07-Mar-01	18-Mar-14
Westinghouse	LEU, 5.00%, & Nat U, in various forms	Change licensee to Westinghouse	07-Mar-01	18-Mar-14
Thermo Fisher Scientific	HEU, 94.0% in fission chambers - 281 g	Neutron Flux Monitoring System - Shin Kori Units 1, 2, 3, & 4; & Shin-Wolsong Units 1 & 2	22-Oct-08	15-Jan-14
DOE - Oak Ridge	LEU, 19.95% as broken metal - 322 kg	LEU Targets - Hanaro Research Reactor	10-Sep-09	31-Dec-12
Manufacturing Sciences Corporation	DU, as unalloyed metal - 800 kg	Fabrication experiments & R&D of fuel for sodium-cooled fast reactors - KAERI	28-Apr-11	31-Dec-14

Source: NRC.

Note: PWR=pressurized water reactor; LEU=low-enriched uranium; HEU=highly enriched uranium; DU=depleted uranium.

In addition to NRC licenses for exporting nuclear materials and reactor components, U.S. companies conducting nuclear-related business abroad may require authorization from DOE under 10 CFR Part 810, which implements Section 57b of the Atomic Energy Act. Section 57b requires DOE authorization for any company or person who wants to "directly or indirectly engage in the production of any special nuclear material outside of the United States." These activities usually involve nuclear technology transfer and engineering and consulting services. For example, an 810 authorization was required for the transfer of Westinghouse reactor technology from South Korea to the UAE.

The value of U.S. nuclear exports that could be dependent on the extension of the U.S.-ROK 123 agreement extension is difficult to estimate. The United Nations Commodity Trade Statistics Database (Comtrade) shows U.S. exports to Korea of nuclear components and fuel elements totaling a modest $181.8 million from 2001 through 2010. However, some of the large exports under the licenses listed in **Table 1**, such as reactors and major components, are estimated to have a value of up to $200 million apiece.[46] Therefore, it appears that the total value of those exports is higher than shown in the Comtrade data base search.

In the nuclear materials area, the major U.S. uranium enrichment company, USEC, signed a contract in October 2007 totaling $400 million with South Korea through 2013. The contract included new and existing delivery commitments and averages about $67 million per year.[47] U.S.

[46] E-mail from Daniel Lipman, Nuclear Energy Institute, October 16, 2012.

[47] USEC Inc., "USEC, Korea Hydro & Nuclear Power Sign New Fuel Supply Contract," news release, October 24, 2007.

exports of natural uranium to Korea appear to be substantially smaller, since exports of U.S.-origin uranium to all countries averaged only $19 million from 2007-2011.[48]

The UAE Barakah plant is the largest current Korean-U.S. nuclear project that could be affected by a lapse in the U.S.-ROK 123 agreement. As discussed above, about $2 billion of work on Barakah is expected to go to U.S. companies. Much of that work will consist of U.S.-made components exported directly to the UAE, which has its own 123 agreement with the United States, so those exports would probably not be directly affected by the U.S.-ROK agreement. However, some components and subcomponents will be exported to Korea for further fabrication and subsequent shipment to the UAE. Any of those components requiring NRC specific licenses could not be exported without a 123 agreement. Most of the subcomponents being sent to Korea are probably covered by the NRC general license or need no NRC license. As discussed above, the effect of a lapse on general license exports is less clear. Also uncertain would be the effect of a lapse on the DOE 810 authorizations for technology transfer associated with the project. Because of the importance of the Barakah project for South Korea's nuclear export plans, any uncertainty and potential for delay related to the status of the 123 agreement would undoubtedly be a major source of concern for all parties.

Other major U.S.-Korean nuclear projects that could be affected are four reactors being built at two sites in China, Sanmen and Haiyang. The Chinese reactors are the first Westinghouse AP1000s, the company's most advanced design, incorporating "passive" safety features and modular construction techniques. Because major components for these reactors are being made in South Korea, some of the same uncertainties faced by the UAE project could apply to subcomponents from the United States.

Lapses in 123 agreements have occurred in the past. One major example was the expiration of the U.S. agreement with the European Atomic Energy Community (Euratom) at the end of 1995. A new 123 agreement had been negotiated when the old one expired, but it had been submitted for congressional review on November 29, 1995, too late for the required 90 days of continuous session. NRC suspended specific and general licenses for most Euratom countries on January 4, 1996, allowing exports to continue only to four countries that had submitted bilateral nonproliferation assurances.[49] However, additional assurances were supplied in time to prevent a significant interruption in U.S. exports to Euratom, and, despite some congressional controversy, the new agreement took effect in March 1996.[50]

U.S. Policy Considerations

The future direction of U.S.-South Korean cooperation in world nuclear energy markets poses a number of near- and long-term policy considerations for the United States. U.S. policymakers will face decisions related to U.S. nuclear energy cooperation with Korea that will affect broader

[48] Energy Information Administration, "Foreign Sales of Uranium from U.S. Suppliers and Owners and Operators of U.S. Civilian Nuclear Power Reactors by Origin and Delivery Year, 2007-2011," *2011 Uranium Marketing Annual Report,* May 2, 2012, http://www.eia.gov/uranium/marketing/pdf/umartable21figure19.pdf.

[49] "U.S.-Euratom Agreement Beneficiary of Budget Stalemate in Washington," *NuclearFuel*, January 15, 1996, p. 16.

[50] Kathleen Hart, "Challenges to U.S.-Euratom Accord Fade as Congress' Review Concludes," *NuclearFuel*, March 11, 1996, p. 9.

U.S. policy goals. In turn, U.S. decisions based on broad policy goals will have an effect on Korean involvement with the U.S. nuclear industry.

The most immediate challenge facing U.S.-ROK nuclear cooperation is the renewal of the 123 agreement, as discussed above. As with most U.S. nuclear cooperation agreements, the existing Korean agreement requires U.S. consent for any reprocessing or enrichment activities related to U.S.-supplied materials and technology. Korea is requesting that the new 123 agreement include U.S. advance consent for future Korean civilian reprocessing and enrichment activities. The United States has reacted skeptically to the idea, on grounds of general nonproliferation policy and the complications that such activities might pose for other security issues on the Korean peninsula. The outlook for a new 123 agreement is further complicated by the February 25 change in presidential administrations in South Korea. Although the ruling conservative party remains in power, the negotiating positions of new ROK President Park Geun-hye on this issue are unclear.

The degree to which the United States retains control over the South Korean nuclear program has led to proposals for South Korean "nuclear sovereignty." As reported in the Korean news media, the term has been applied to restrictions ranging from the current U.S. restrictions on South Korean spent fuel reprocessing to approvals of technology exports, such as the UAE sale. South Korean Minister of Knowledge Economy Choi Kyung-hwan in late 2009 clarified that the term does not refer to nuclear weapons development by using the phrase "peaceful nuclear sovereignty." Choi called the current U.S. restrictions on Korean spent fuel reprocessing "excessive," and pointed to the UAE sale as evidence of, as paraphrased in a Korean news report, "global confidence in South Korea's ability to handle the task."[51] Koreans regularly note that the United States for decades has granted advance consent for reprocessing to the Euratom countries and Japan, and argue that Korea, with its well-developed nuclear power program, should be treated equivalently. U.S. recognition of South Korea's rights to engage in all peaceful nuclear fuel cycle activities, whether or not it chooses to actually do so, appears to be an element of the nuclear sovereignty concept.

Korean officials contend that their nuclear industry must reprocess its spent fuel to forestall a looming waste storage crisis. The Korean nuclear industry had previously estimated that spent fuel pools at some sites would run out of space beginning in 2016. A recent analysis calculates that, if spent fuel from older storage pools can be shifted to newer pools at each plant site, that date could be pushed back to the early 2020s, starting at the Yonggwang site. Expansion of non-pool "dry" storage facilities is considered politically and legally problematic in South Korea. KAERI's program to develop pyroprocessing technology, as discussed above, could allow uranium and plutonium from spent fuel to be recycled in fast reactors (reactors whose neutrons have not been slowed by water or other moderators), which also must be developed. Although such a "closed" fuel cycle could not be implemented before existing spent fuel pools run out of space, supporters contend that it would increase public acceptance of the necessary additional waste storage facilities.[52] Supporters of a closed fuel cycle also say it could provide a secure, domestic energy source by extracting plutonium and uranium for multiple recycling in fast reactors.

[51] "Seoul Wants 'Sovereignty' in Peaceful Nuclear Development," Chosun Ilbo, December 31, 2009.

[52] Jungmin Kang, Korea Advanced Institute of Science and Technology, "The ROK's Nuclear Energy Development and Spent Fuel Management Plans and Options," 2012.

Korea's request for advance consent on uranium enrichment is based on its desire to provide full fuel supply contracts to potential reactor customers, to better compete in the world market with such rivals as the French firm Areva. Critics of that argument have pointed out that Korea won the UAE reactor contract in direct competition with Areva. However, the Korean industry may be calculating that it would not have to offer deep discounts, as reportedly was the case with the UAE, if it could provide complete fuel supply services as part of its reactor sales. Korea would also like to reduce its reliance on foreign uranium enrichment providers, to which it pays about $300 million per year.[53] An enrichment plant in Korea might be based on the "black box" model, in which a foreign country constructs a plant without revealing key information about the technology to the host country.

U.S. policy has long opposed the expansion of enrichment and reprocessing to additional countries, because of concern that the technology, even if initially for civilian purposes, can be used to make weapons materials. Granting advance consent to South Korea could undermine that policy by encouraging other countries to make similar requests in the future and making it harder for the United States to turn them down. There are also U.S. concerns that granting consent for enrichment and reprocessing in South Korea could complicate efforts to persuade North Korea to adhere to the Korean Peninsula denuclearization agreement and give up its nuclear weapons program.

Because of the strongly differing views between the United States and South Korea on reprocessing and enrichment, negotiations on renewing the 123 agreement have proved challenging. Lack of progress on those issues led the two countries to announce a two-year extension of the existing agreement on April 24, 2013. Legislation to authorize the two-year extension was introduced by Representative Royce on June 20, 2013 (H.R. 2449). The additional time could allow negotiators to explore a wide range of potential compromise approaches for a new agreement:

- *Short-term agreement.* Existing restrictions on reprocessing and enrichment could be continued in a relatively short agreement, perhaps coinciding with the completion of the 10-year joint pyroprocessing feasibility study. Decisions on advance consent, taking into account the results of the study, would then need to be made in a subsequent agreement.
- *Advance consent with conditions.* A new agreement could provide advance consent for reprocessing and enrichment, but South Korea would agree not to exercise that right until certain conditions were met. For example, milestones might need to be met regarding the Korean Peninsula denuclearization agreement.
- *Advance consent for limited activities.* The United States could grant advance consent for a limited set of fuel cycle activities. An example might be the operation of KAERI's Advanced Conditioning Pyroprocess Facility, which reduces oxide spent fuel to metal form for pyroprocessing. This reduction process results in relatively little separation of plutonium and uranium.

In addition to the 123 agreement, Korea's ambitious plans for future reactor exports would require further DOE 810 authorizations for the transfer of U.S.-based technology. Under Section

[53] Seongho Sheen, "Nuclear Sovereignty versus Nuclear Security: Renewing the ROK-U.S. Atomic Energy Agreement," *Korean Journal of Defense Analysis*, Vol. 23, No. 2, June 2011, pp. 273-288.

57b, the Secretary of Energy must determine that each proposed technology export "will not be inimical to the interest of the United States" with the concurrence of the Department of State and after consultation with NRC and the Departments of Commerce and Defense. Such reviews would examine U.S. interests in the relevant region and throughout the world, such as controls on the re-transfer of U.S.-origin nuclear technology after it is exported by Korea.

Future growth of South Korea's nuclear energy technology export program would offer opportunities for the U.S. nuclear industry as well as significant challenges. As the KEPCO-UAE sale makes clear, U.S. companies can directly benefit from participation in Korean export projects, in this case an estimated $2 billion for Westinghouse and its subcontractors. But the UAE project also illustrates the potential competition that U.S. nuclear suppliers may face from Korea, which overcame a GE-Hitachi bid in the final round and an earlier Westinghouse proposal. As the South Korean nuclear industry develops more reactor components of indigenous design, the opportunities for U.S. participation in South Korean export projects may diminish. Government ownership of KEPCO may also be a competitive concern for U.S. industry. A World Nuclear Association report notes that South Korea may develop a large, exportable reactor design based on the APR-1400 with indigenous components by 2015, "though Westinghouse is not likely to let it compete in main markets such as USA and China without KEPCO buying the rights to the design."[54] Such issues related to South Korean "peaceful nuclear sovereignty" are likely to be a topic of continuing U.S.-ROK discussion.

Author Contact Information

Mark Holt
Specialist in Energy Policy
mholt@crs.loc.gov, 7-1704

[54] World Nuclear Association, "Nuclear Power in South Korea," op. cit.